Appendix C

Probable Maximum Flood Study

7-1596B(9-89)
Bureau of Reclamation

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FOLDER I.D.:

D-8530
PRJ-13.10

JAN 12 2004

MEMORANDUM

To: Team Leader, Black Rock Dam Design Team
Attention: D-8120 (LaFond)

From: Kenneth Bullard, Hydraulic Engineer
Flood Hydrology Group
Technical Service Center
Kenneth L. Bullard

Subject: Feasibility Design Level Probable Maximum Flood (PMF) Study and Frequency Floods for Diversion During Construction for Black Rock Dam, Washington

The attached report provides the requested feasibility design level probable maximum flood for Black Rock Dam. The current plans call for the dam to be built with no emergency spillway and the entire volume of the PMF hydrograph to be contained in flood surcharge space. For this reason the winter general storm with a larger volume should be considered for the feasibility level designs.

If future plans call for the dam to have some form of emergency spillway, then the summer general storm or the summer local storm PMF with larger peak flows should be considered. If future plans call for a significantly lower, or higher normal water surface than the assumed 1,800 feet then the PMF study should be redone to account for this change in the basin hydrologic characteristics. Before any final designs are completed for Black Rock Dam, a site visit by a qualified flood hydrologist should be made to verify the soil and runoff characteristics of the basin as well as provide a review and check of the current study for any other final design level considerations.

If you have any questions regarding this study please contact me at 303-445-2539 or E-mail at kbullard@do.usbr.gov.

Attachments

bc: D-8130 (Stanton), D-8530 (Bullard/Schreiner/File)

WBR:KBullard:amv:1-5-04:445-2539
(I:8530:BlackRock.MKB.doc)

Black Rock Dam, WA
(PMF)

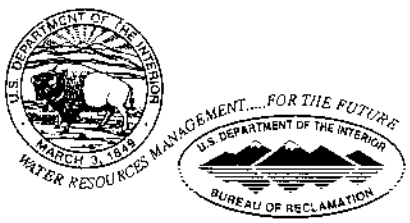
TECHNICAL SERVICE CENTER
Denver, Colorado

BLACK ROCK DAM
WASHINGTON

Feasibility Level Probable Maximum Flood Study

Prepared by
Flood Hydrology Group
Water Resources Services

U.S. Department of the Interior
Bureau of Reclamation



DECEMBER 2003

Black Rock Dam, Washington
Feasibility Level Probable Maximum Flood Study

Authorization: Funds for studies related to the feasibility of construction of Black Rock Dam were included in the Energy and Water Development Appropriations Act for Fiscal Year 2004 signed into law on December 1, 2004. The Bureau of Reclamation had begun preliminary investigations into the proposed dam location for Black Rock Dam, Washington in FY2003. As part of the preliminary investigations for this dam a feasibility level Probable Maximum Flood study was requested. Specific authorization for the Flood Hydrology Group to proceed with this study was contained in a LAN message from the team Reclamation leader in November 2003.

Summary of Results:

Table 1
Black Rock Dam, Washington
Feasibility Level PMF Study

Flood Description	Peak (ft^3/s)	Volume (acre-feet)	Duration
Winter General PMP Storm (with 100-yr antecedent rain flood – Nov. – Mar.)	20,200	29,100	10.5 days
Summer General PMP Storm (with no antecedent flood June – Oct.)	28,900	28,900	3.5 days
Summer Local PMP Storm (with no antecedent flood June - Oct)	74,900	17,000	1-day

These hydrographs are displayed in figures 1, 2 and 3 and on tables 1, 2, and 3.

Previous Studies: There are no known previous PMF studies of this basin.

Project location and basin description: Black Rock Dam is to be located in south central Washington State near the eastern boarder of Yakima County where it crosses the existing highway 24 on what is referred to locally as Dry Creek. The dam is a potentially large structure with a hydraulic height of 400 feet or more. Most of the water for storage will be pumped from the Columbia River at Priest Rapids Dam during times of the year when excess water may be available at that location. The dam has a small natural drainage area with a large lake surface covering about 20 percent of the natural basin. It is envisioned that the dam will have enough freeboard to completely contain a full PMF

(including any antecedent flood) with out using an emergency spillway. Water from the dam will be pumped into a pipeline and delivered to meet irrigation needs in the Yakima River basin to the west at beneficial times of the year.

The basin is described as being mostly steep slopes with grass and weed-cover. The basin area was measured using the WMS (Brigham University, 1999) computer program and available 1:250000 scale, with 30-meter resolution for elevation data points, USGS (United States Geological Survey) DEM (Digital Elevation Models). The total drainage area from this measurement was 61.2 square miles. Additional capabilities of the WMS model were used to determine the lake surface area at a proposed elevation of 1,800 feet. This elevation produces a lake surface area of 12.0 square miles based on the 1:250000 scale maps.

Some difficulties were encountered in the drainage area measurement processes using WMS. The basin straddles two UTM (Universal Transverse Mercator) zones. Since the dividing line between UTM zone 11 and zone 12 is the 120 degree longitude line, it was not possible to find a set of 7 ½ minute DEMs or DRGs (digital raster graphics) maps that could be readily incorporated into the WMS model. The difference in the UTM zones requires additional GIS processing to bring everything into one zone. This was not done for this feasibility level study because it was felt that the 1:250000 DEM maps would provide adequate information. The use of the 1:250000 maps at a 30-meter interval spacing between elevation points is somewhat less accurate than would be the 7 ½ minute DEM maps at a 10-meter elevation spacing. It appears there are some areas in the southwestern corner of the basin as drawn by WMS that may not flow into Black Rock Reservoir if more detailed maps are used. The drainage area and lake surface areas and other basin parameters based on the 1:250000 maps should be checked with the more accurate maps before final designs for this proposed structure.

Figure 4 provides a general location and basin boundary map with the proposed lake surface elevation of 1,800 feet identified.

Probable Maximum Precipitation Study: The Black Rock Dam basin is located in a region covered by Hydrometeorological Report Number 57 (NOAA, 1994) for the purposes of defining PMP (Probable Maximum Precipitation).

In determining PMP using the HMR 57 the month of occurrence of the storm is needed. It was anticipated that the winter conditions (November – March) would produce the maximum precipitation amounts for this type of study. However, on examination of the data in HMR 57 it was discovered that the PMP event for the summer months, June – October, would be approximately 20 percent larger.

It was also noted that larger antecedent floods would be more likely to occur in the winter months. Since the dam is being considered to have enough freeboard storage to completely contain a full PMF, including any antecedent flooding, both the winter and summer general storm conditions were considered in this feasibility study. For future reference a summer local storm (thunderstorm) PMP was calculated. This type of storm is generally much more intense and produces much higher peak flows, but with significantly lower flood volumes.

In calculating the PMP amounts an approximate total basin area of 60 square miles was used for area reductions to the point PMP. The mean basin elevation of 2,220 feet was calculated from the WMS program and was also used in the PMP calculations.

The tables 4 and 5 summarize the accumulated values of aerially reduced PMP calculated for the Black Rock basin. Figures 4 and 5 of this report display a depth versus duration plots of these PMP data.

Table 4
Summary of General Storm Probable Maximum Precipitation Estimates
Black Rock Dam, Washington

Time from Start of Storm (hours)	General storms Winter (inches)	Summer (inches)
0	0.00	0.00
1	1.00	1.18
6	3.37	3.97
24	6.56	7.73
48	9.20	10.84
72	10.25	12.07

Table 5
Summary of Local Storm Probable Maximum Precipitation Estimates
Black Rock Dam, Washington

Time from Start of Storm (hours)	Local Storm Summer (inches)
0.00	0.00
0.25	1.88
0.50	3.13
0.75	3.95
1.0	4.55
2.0	5.09
3.0	5.23
4.0	5.37
5.0	5.44
6.0	5.50

The data from the depth-duration plots were input to the Bureau of Reclamation's FHAR (Reclamation, 1986) rainfall-runoff program. This program reads the smooth incremental depths of PMP. Placing the maximum incremental rainfall value at the 2/3 point of the storm duration and alternating the remaining incremental values in decreasing order about this point creates the design storm sequence. This rainfall distribution is the standard PMP design storm arrangement as specified in the Bureau of Reclamation's Flood Hydrology Manual (Cudworth, 1989).

Basin Lag Times and Unit Hydrograph Computations: The standard Bureau of Reclamation Lag time equation was used to develop unit hydrographs for the different storm conditions on this basin. The lag time is computed b the following equation:

$$Lag = C*[(L * Lca)/(S)^{0.5})]^{0.33} \text{ (hours)}$$

Where:

C = a runoff efficiency coefficient for a basin and storm type
L = Length of the longest water course (miles)
(Measured to the upstream edge of the reservoir at the top of active conservation elevation)
Lca = Length to the centroid of the basin (miles)
(Measured along the longest water course)
S = Slope along the longest water course (feet/mile)

The HEC-WMS program computed the required lengths and channel slopes with topography data input from available USGS 30-meter DEMs. In this case, the total basin consists of several small parallel side channels flowing from north to the south, or south to north, and into the proposed lake at elevation 1,800 feet. Normal basin calculations start at a point at the upstream end of the reservoir at a normal water surface and follow the longest water course upstream to a saddle point on the basin boundary. The distance to a point along this main channel to a point opposite the basin centroid, and the distance to the basin centroid from the main channel are also measured. In this instance with many side channels, the total basin centroid would be located inside the proposed lake surface and the calculated Lca distance by normal methods would be in error.

To resolve the problems associated with the many small inflow channels, a single subbasin was created at the extreme northwest end of the total basin. This small subbasin had its downstream concentration point located at the proposed lake surface and the upstream end extended to the original total basin boundary. This small subbasin was judged to be the largest such subbasin that could be drawn within the total basin. The WMS program was used to calculate the necessary measurements for L and Lca and the slope values for this subbasin. The lag time calculated from this subbasin was then allowed to represent all of the other similar subbasins that could be defined. Figure 7 displays a map from the WMS program to illustrate the use of the selected subbasin to calculate the lag parameters.

Table 6 displays the various measurements and estimates of the "C" value used to establish the lag times for the total basin and the different storm conditions for the Black Rock basin.

Table 6
Black Rock Dam, Washington
Lag time computations

Season	Parameter	Value	Units
Winter	C	2.6	
	L	5.11	miles
	Lca	4.00	miles
	S	214.90	Feet/mile
	M	0.33	none
	Lag	2.90	hours
	D	0.5	hours
Summer	C	1.6	
	L	5.11	miles
	Lca	4.00	miles
	S	214.90	feet/mile
	M	0.33	none
	Lag	1.79	hours
	D	0.3	hours

The choice of the "C" parameter was made without the benefit of a site visit. The values chosen are similar to those for other Reclamation PMF studies that have been prepared in the region. In this instance the actual "C" value and the resulting lag times are not critical since the dam will be designed to contain the entire volume of the PMF. The lag time computations only affect the peak and not the volume of the computed PMF hydrographs.
Complete hydrographs are generated to assure that the proper volume of flooding is obtained for each critical duration.

The dimensionless graph selected for use with this study was originally prepared for Bully Creek Dam. This dam is in the western portions of the Yakima River basin and is the most representative of all of the available dimensionless graphs in the Reclamation collection. The same dimensionless graph was used for both the winter and a summer condition with only a change in the "C" value to help account for the potentially more intense summer rainfall. A different dimensionless graph could have been selected for the local storm PMF to help account for the even more intense rainfall. However the Bully Creek Dam dimensionless graph already has a peak flow of 30 ft^3/s, which is higher than the Rocky Mountain thunderstorm dimensionless graph peak. It is also true that the local storm PMF volume is not likely to control any design process and the actual dimensionless graph used is not significant in this process. The process to convert the dimensionless graph to a unit hydrograph is described in the USBR Flood Hydrology Manual (USBR, 1989).

Loss Rates: Figure 8 depicts the general soil hydrologic classifications taken from the NRCS STATSGO database (NRCS, undated) for this basin. It is important to realize that the proposed water surface at elevation 1,800 feet occupies about 20 percent of this total basin area. For the different hydrologic soil groups indicated the USBR Flood hydrology manual provides minimum

loss rates to be used. The minimum loss rates for the various soils groups in this basin are indicated on figure 9. The various soil groups were measured using ARCVIEW and the resulting areas were used to help compute an area weighted constant loss rate for use on all of the land areas of this basin. Table 7 displays the measurements and computations used to derive the final constant loss rate for the entire land surface area of this basin.

The constant loss rate of 0.06 inches per hour is used with both the summer and winter conditions. There is no snow cover assumed on this basin during the winter season and loss rates associated with snow cover do not need to be considered.

Table 7

Black Rock Dam, Washington
PMF Study Infiltration Analysis

Soil Group	Sq. Mi.	Min Loss	Area*Loss	
B	5.0	0.15	0.75	
C	40.0	0.05	2.00	
D	4.0	0.00	0.00	
Total	49		2.75	
Weighted Average			**0.06**	**in/hr**

Lake Surface is treated separately with 0.0 in/hr on 12.0 square miles

By definition the PMF hydrographs calculated by Reclamation assume a very saturated basin prior to the onset of the PMP storm. This assumption allows for the elimination of any initial losses or any decaying loss rate function during the early time periods of the PMP storm. This soils information has not been verified by a field inspection. Prior to any final designs a field investigation of the site should be made by a qualified flood hydrologist to verify the soils and loss rate information used in this study as well as other hydrologic parameters that have been estimated.

Snow Cover Consideration: A check of several snow stations in the state of Washington was made to determine if any potential snow cover should be assumed during the winter or spring months. Figure 9 displays a map showing all of the snow gage stations reported by the NRCS (NRCS, 2003). There are no snow gage stations in the immediate vicinity of the Black Rock Dam drainage basin. There is no reason to believe that significant snowfall collects on this basin. The basin is to far southeast and at to low of an elevation to have prolong periods of snow accumulation. For this study it is assumed that there will be no snow pack on the basin during the winter months. Any antecedent flooding in the winter will be the result of preceding days of rainfall and associated runoff.

Antecedent Flood hydrographs: A further search available stream gage stations also indicated few stations in the area that are geographically near to or similar to the Black Rock Dam basin. The closet hydrologic similar stream gage record is for Providence Coulee near Cunningham, Washington (USGS gage site No. 12512550). This gage has a drainage area of 52.1 square miles and is at an elevation of 1,115 feet. These values are nearly the same as at the Black Rock Dam site. The gage has 19 years of record with from 1978 to 1998,with one missing year (1992). Data for peak flows was obtained from the USGS NWIS WEB site. In the 19 years of record only two maximum annual flood peak events occurred in the summer months, and both of those were very small, (43 ft^3/s and 41 ft^3/s in 1991 and 1994 respectively). All other maximum annual peak flows occurred in the winter months of January through March and has gone over 1,000 ft^3/s on one occasion. A further check of the daily flow records indicated that most summer month days have zero flow. On those summer days when flows are recorded the amount is very small, usually much less than 10 ft^3/s. The flows seldom last more than one or two days. In the winter months much larger daily flows can occur and the stream tends to have flow in it for several days or weeks at a time.

The conclusion of this investigation is that large antecedent floods are most likely to occur in the winter months but are not likely at all in the summer months. If they did occur in the summer they would have insignificant volumes compared to any PMF hydrograph volume. The PMF computations were based on this set of data with no antecedent flood for the summer conditions either for the general storm or for the local storm. It is a common Reclamation practice to produce local storm PMF hydrographs for summer months, in portions of the western United States, with no antecedent flood.

The winter months were further analyzed to produce estimates of the 100-year, 1-, 3-, and 7-day maximum daily flood flows. Tables 8, 9 and 10 display the frequency computations of the maximum daily flows. These estimates were then adjusted by the square root of the drainage area ration $((61.2/51.1)^{0.5} = 1.09)$ to make them more representative of the total drainage area above Black Rock Dam. These 100-year flow estimates were then used to form a 7-day balanced hydrograph by placing the maximum 1-day flow value in the center, the flow value equal to ½ of the volume of the maximum 3 days maximum 1-day value on the two surrounding days, and the flow value equal to ¼ of the volume of the maximum 7-days minus the maximum 3-days for the outside four days. The resulting 100-year balanced hydrograph for the winter months above Black Rock Dam was then considered to be an antecedent flood that could occur with a peak 3 days prior to the start of the PMP. The 3-day separation of the antecedent rain flood is recommended in the Reclamation Flood Hydrology Manual for this region of the country. Table 11 below lists the relevant data derived from this process for the 100-year 7-day winter antecedent flood.

Table 11
Black Rock Dam, Washington
100-year 7-day winter antecedent flood

Day	Average Flow (ft^3/s)
1	159
2	159
3	316
4	1728
5	316
6	159
7	159

This hydrograph can be seen in the winter general storm PMF hydrograph sequence displayed on figure 1. The primary purpose of this hydrograph is to provide the additional volume of flooding that could be associated with the winter general storm PMF conditions. It is not intended that this hydrograph represent any historic flood event.

Rain on Reservoir Computations: Because the reservoir surface area at elevation 1,800 feet covers a large portion of this basin, approximately 20 percent, the reservoir surface area was treated separately in the calculations. The design rainfall at each computation interval was placed over the reservoir surface with no losses considered. This gave a depth of rainfall over the 12.0 square mile water surface. This is a volume of water in a specified time interval. This value was then converted to an average reservoir inflow (in ft^3/s) for the specified time period for each storm type. The conversion factor is that 1 inch of water on one square mile of lake surface in 1 minute is the equivalent volume of 38,720 ft^3/s stream flooding entering the reservoir for 1 minute. To make use of the conversion factor it is multiplied by the total depth of rainfall (inches) in each computation interval, then multiplied by the total lake surface size (square miles) and then divided by the computation time increment (minutes) for each time interval in the storm sequence. The resulting hydrograph was then placed into a FHAR input hydrograph file and added with the appropriate PMF rainfall-runoff h hydrograph computation from the land portions of the basin for the storm type being considered. This computation often produces a leading peak on the combined hydrograph that is the result of the rain on the reservoir surface.

Pumping Inflows: A considerable volume of water will be added to the reservoir at certain times of the year by pumping from the Columbia River above Priest Rapids Dam when conditions permit. The exact details of this pumping scheme have not been worked out at the time of this study. It should be certain that under any conditions the pumping would cease when the reservoir reaches the maximum elevation of 1,800 feet. If the reservoir is assumed to be at a lower elevation at the start of the PMP storm then some additional pumping flows might also be considered. In all cases the worst possible condition for storing potential flood water would be when the PMF flood hits the reservoir after the maximum reservoir water surface of 1,800 feet is

reached. For this reason no additional inflows due to pumping are considered in this feasibility level PMF hydrograph study.

PMF Rainfall-Runoff Computation: All of the data derived for the basin; the design storm arrangement, the loss rates, the unit hydrographs, the antecedent 100-year snowmelt flood, and the rain on the reservoir hydrographs for each storm sequence were placed in the Bureau of Reclamation's FHAR rainfall-runoff program to generate the final PMF hydrographs for Black Rock Dam.

For the winter general storm PMF, the combined land and reservoir surface hydrographs were lagged by 156 hours (312 time steps) and then added to the antecedent 100-year 7-day flood that was assumed to be based on antecedent rainfall. This was done to place the start of the PMP storm 72 hours after the peak of the antecedent 7-day flood.
Based on examination of available stream gage records that are applicable to the basin there was no antecedent flood assumed with the summer general storm or local storm PMF conditions.

The resulting PMF hydrographs are displayed graphically in figures 1, 2, and 3 and numerically in tables 1, 2, and 3. Because no flood routing of the actual PMF hydrographs is anticipated the values in the tables for the general storm PMF hydrographs are at 2-hour time steps. The actual computations were carried out at ½ hour time steps. The hydrographs at the smaller time interval are available with the backup data for this report in the Flood Hydrology Group files in the Denver Office of the Technical Service Center. Input and summary output pages from the FHAR program are included with Appendix A of this report.

Flood Routing Recommendation: For feasibility level design studies it is not anticipated that any formal flood routings of the PMF hydrographs will take place. The dam is to be designed to contain the entire volume of the PMF hydrograph and any antecedent flooding with out the use of an emergency spillway. Only the total volume of the incoming flood is required. This volume will then be added to the lake surface at elevation 1,800 feet to determine the required flood storage space in the reservoir.

If future design requirements suggest a formal flood routing is required, then the reservoir should be assumed to be full to elevation 1,800 feet and inflow equal to outflow through any available outlet works. No additional pumping should be assumed during the duration of the PMF if the starting elevation of the reservoir is at 1,800 feet.

Diversion During Construction Flood Peaks: Flood peaks for 10-, 25-, and 50-year diversion flood are provided in table 12. These peaks come from an application of the USGS National Flood Frequency Program (USGS, 2002), to the Black Rock Dam basin using the full 61.2 square mile drainage area. No large lake surface is assumed during construction. For application of this program the dam is located in what is termed Region 5 in the state of Washington. The dam is near Region 7, and a check of the values for that region was also made. The Region 5 values are higher for the 10-year to 50-year return periods.

Table 12
Black Rock Dam, Washington
Diversion Flood Peaks
(from USGS NFF Program, Version 3.2, 2002)

Return Period (years)	Diversion Flood Peak (Ft^3/S)
10	897
25	1190
50	1430

These flood peaks are considered to be all season, or the maximum peaks that could occur on an annual basis for the return periods indicated. The NFF program does not provide information about seasonal peak flows.

Envelope Curve Comparisons: Envelope curve comparisons are not provided with this report. The critical values from this PMF study are the volumes of flooding over several days. The PMF peak flows are not important to the design process for this dam. Envelope curves for volumes of flooding from hydrologically similar basins do not exist. The problem is further complicated by the fact that both the computed PMF peak and PMF volume of flooding result from a substantial portion of the basin being a lake surface. There are no data from near by basins that are similar to this situation. Envelope curve comparisons would be meaningless for this level of study and are not provided.

Should future design work require actual flood routing of some of the PMF hydrographs and also require more confidence in the actual PMF peak flow then some envelope curve comparisons could be provided at that time.

Acknowledgement: This report was prepared by Mr. Kenneth L. Bullard, Hydraulic Engineer, with the assistance of Mr. Walter Johnson, Meteorologist. Mr. Lex Kamstra, Hydraulic Engineer, provided peer review. All of these individuals are employed in the Flood Hydrology Group of the Bureau of Reclamation's Technical Service Center in Denver, Colorado.

References:

Watershed Management System (WMS), Copyright 1999 by Brigham Young University, Compiled March 4, 2002.

Hydrometeorological Report 57 (HMR 57) Probable Maximum Precipitation- Pacific Northwest States, United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), United States Department of Interior, Bureau of Reclamation, United States Department of Army, Corps of Engineers, October 1994.

Flood Hydrograph and Routing Program (FHAR), United States Bureau of Reclamation, 1986.

Cudworth, A. G., Flood Hydrology Manual, United States Department of the Interior, Bureau of Reclamation, 1989.

State Soil Geographic (STATSGO) Data Base for the Conterminous United States, United States Department of Agriculture, Natural Resources Conservation Service (NRCS), Data access, (www.ftw.nrcs.usda.gov/stat_data.html).

Snow Course and Monthly SNOTEL Historical Data, United States Department of Agriculture, Natural Resources Conservation Service (NRCS), Data access, (**http://www.wcc.nrcs.usda.gov/snow/snowhist.html**). Updated annually.

NFF, Version 3.2, National Flood Frequency Program, United States Geological Survey, (**http://water.usgs.gov/software/nff.html**), 2002.

Black Rock Dam, Washington
Winter General Storm PMF with 100-Year Antecedent Rainflood

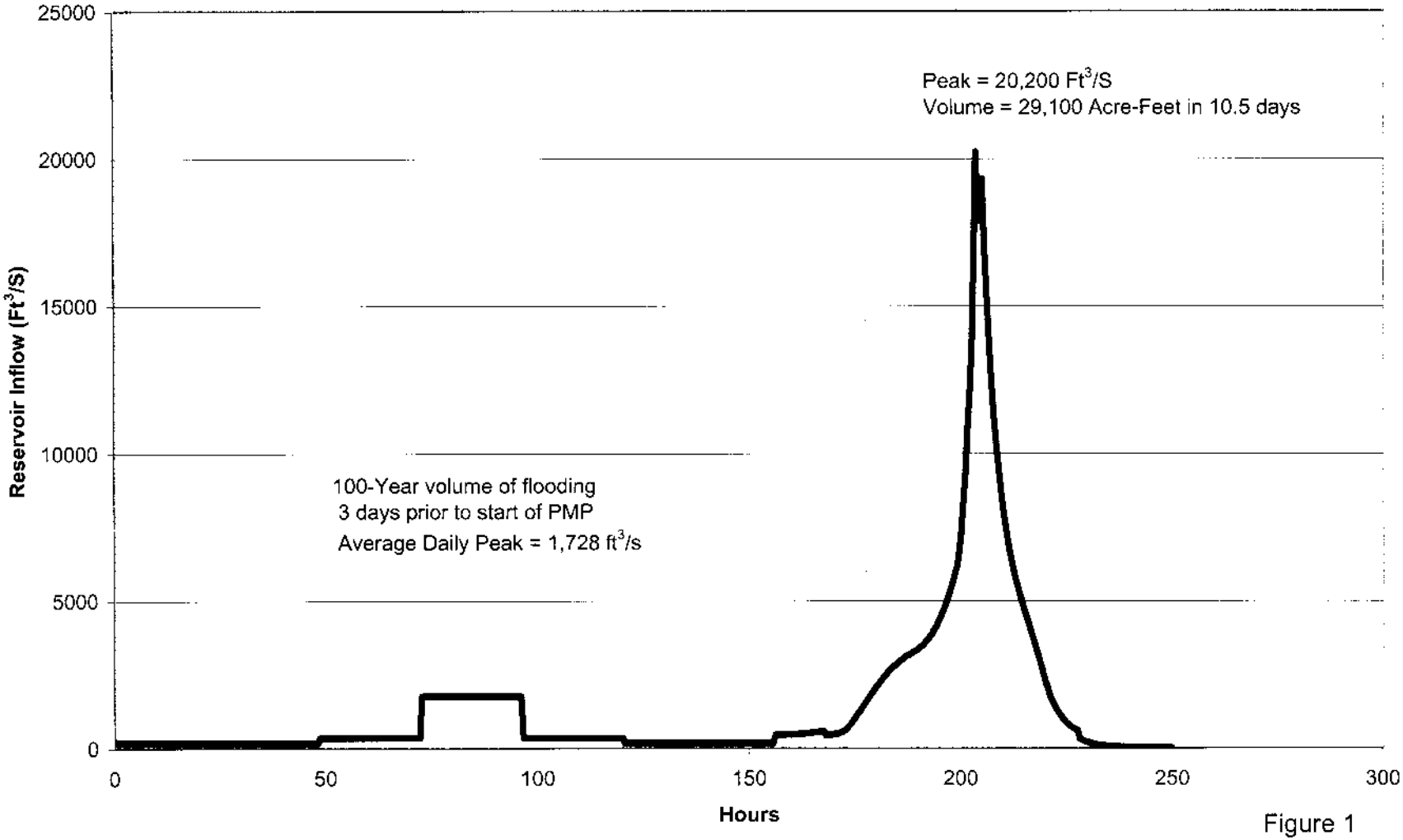


Figure 1

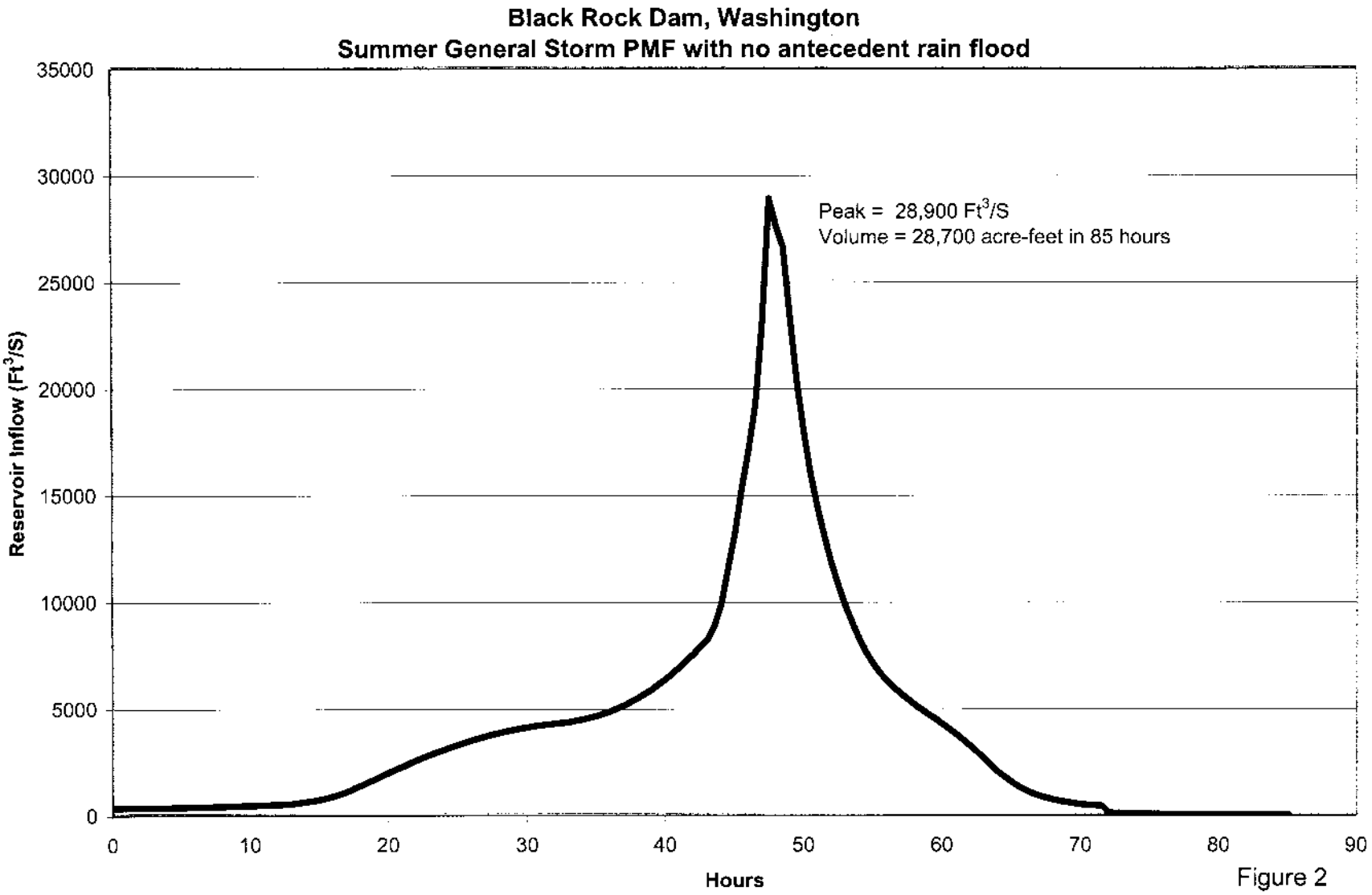

Black Rock Dam, Washington
Summer General Storm PMF with no antecedent rain flood
Peak = 28,900 Ft3/S
Volume = 28,700 acre-feet in 85 hours
Reservoir Inflow (Ft3/S)
35000
30000
25000
20000
15000
10000
5000
0
0
10
20
30
40
50
60
70
80
90
Hours

Figure 2

Black Rock Dam, Washington
Local Storm PMF with no antecedent flood

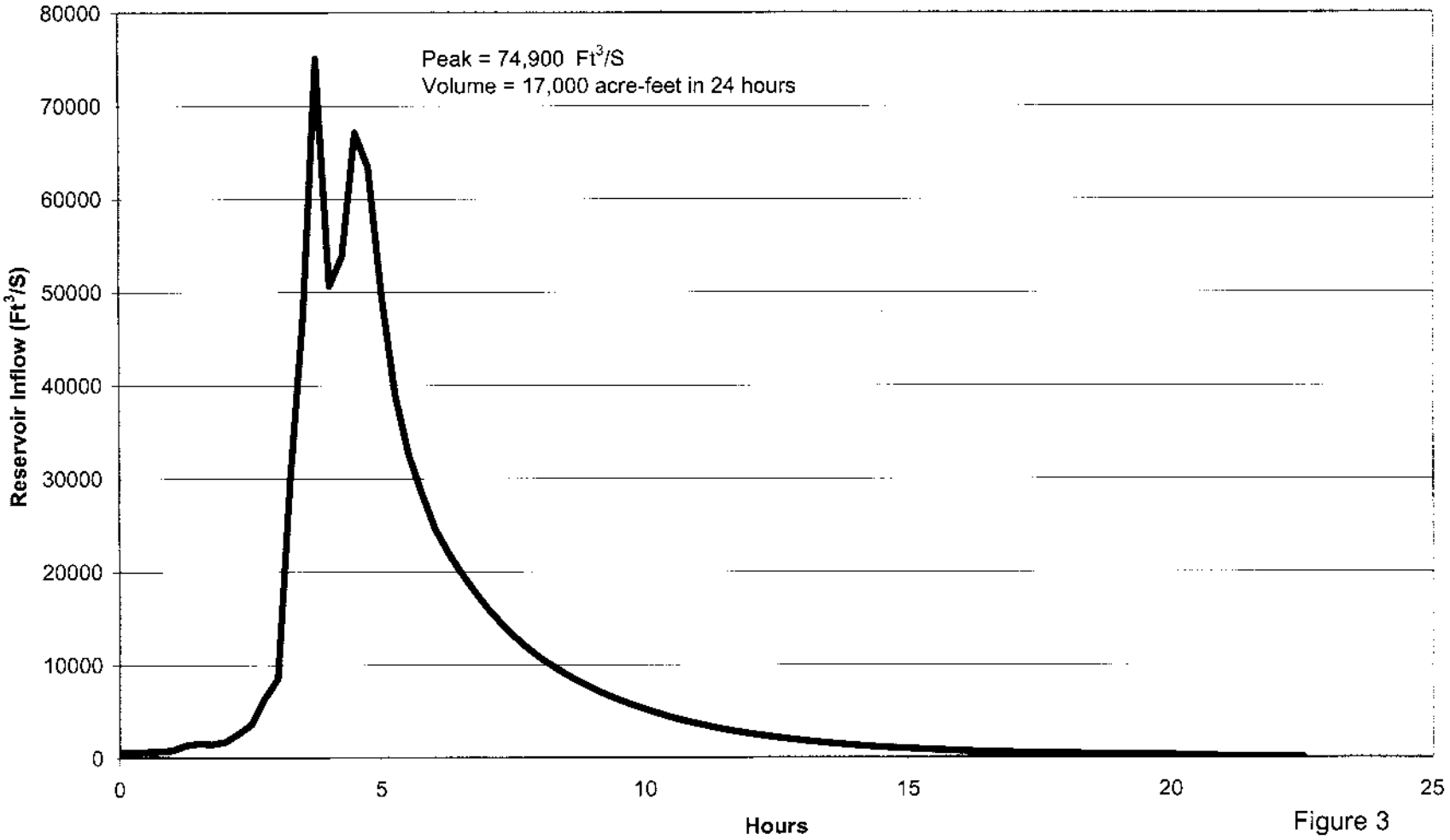


Figure 3

Location and Basin Boundary Map - Proposed Black Rock Dam, WA

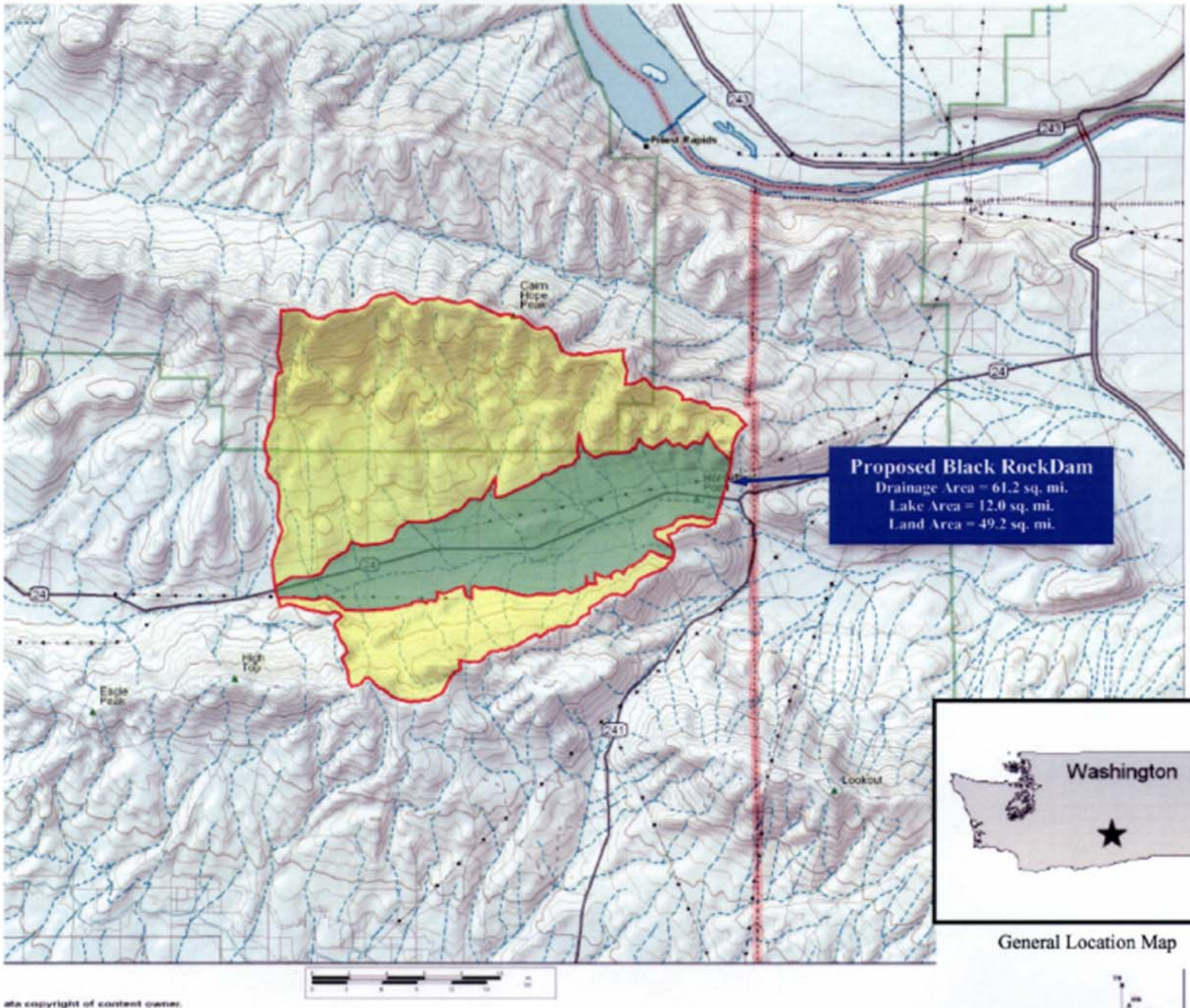


Figure 4

Black Rock Dam, Washington
Summer and Winter PMP Depth-Duration Curves

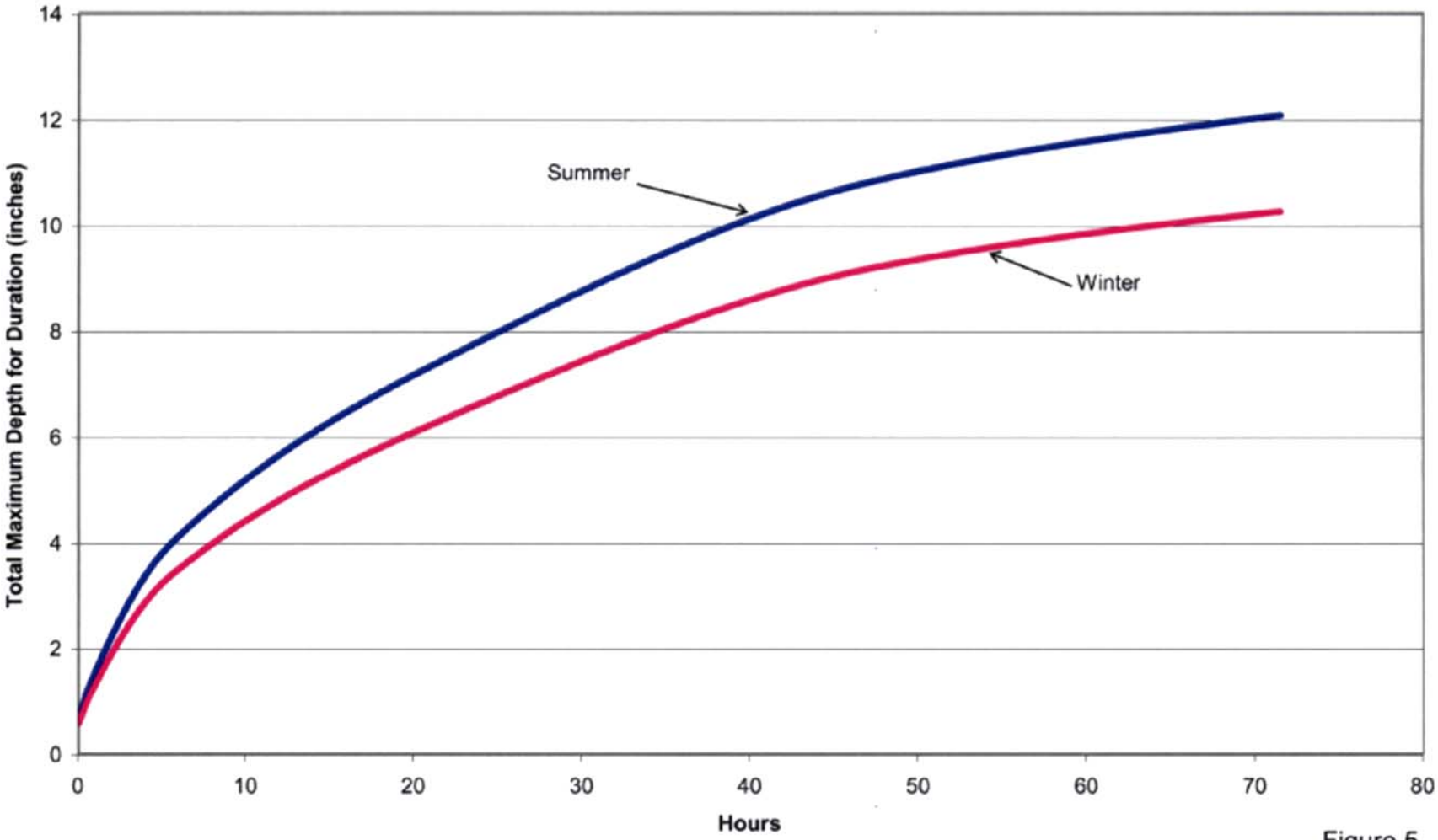


Figure 5

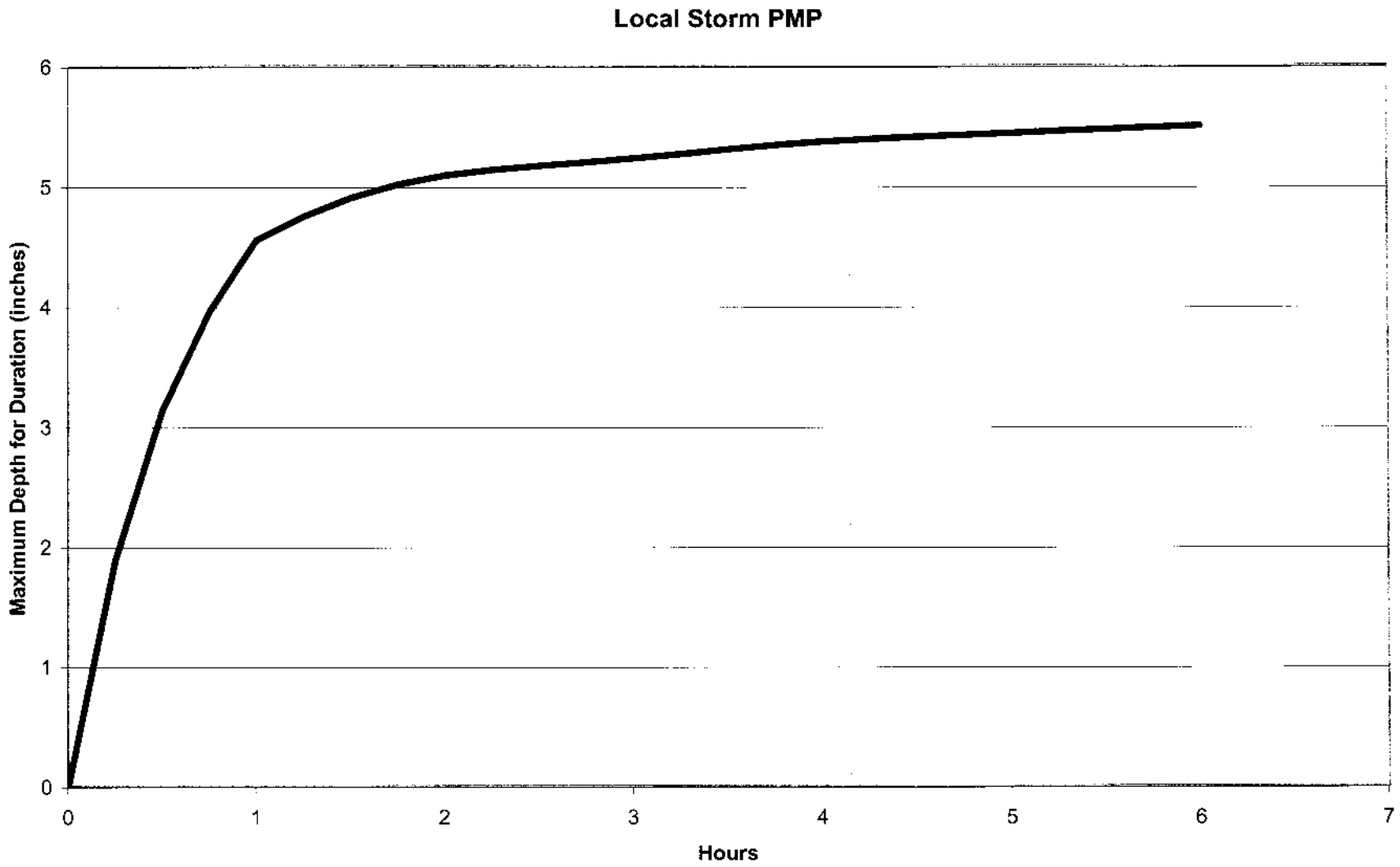

Local Storm PMP
Maximum Depth for Duration (inches)
0
1
2
3
4
5
6
0
1
2
3
4
5
6
7
Hours

Figure 6

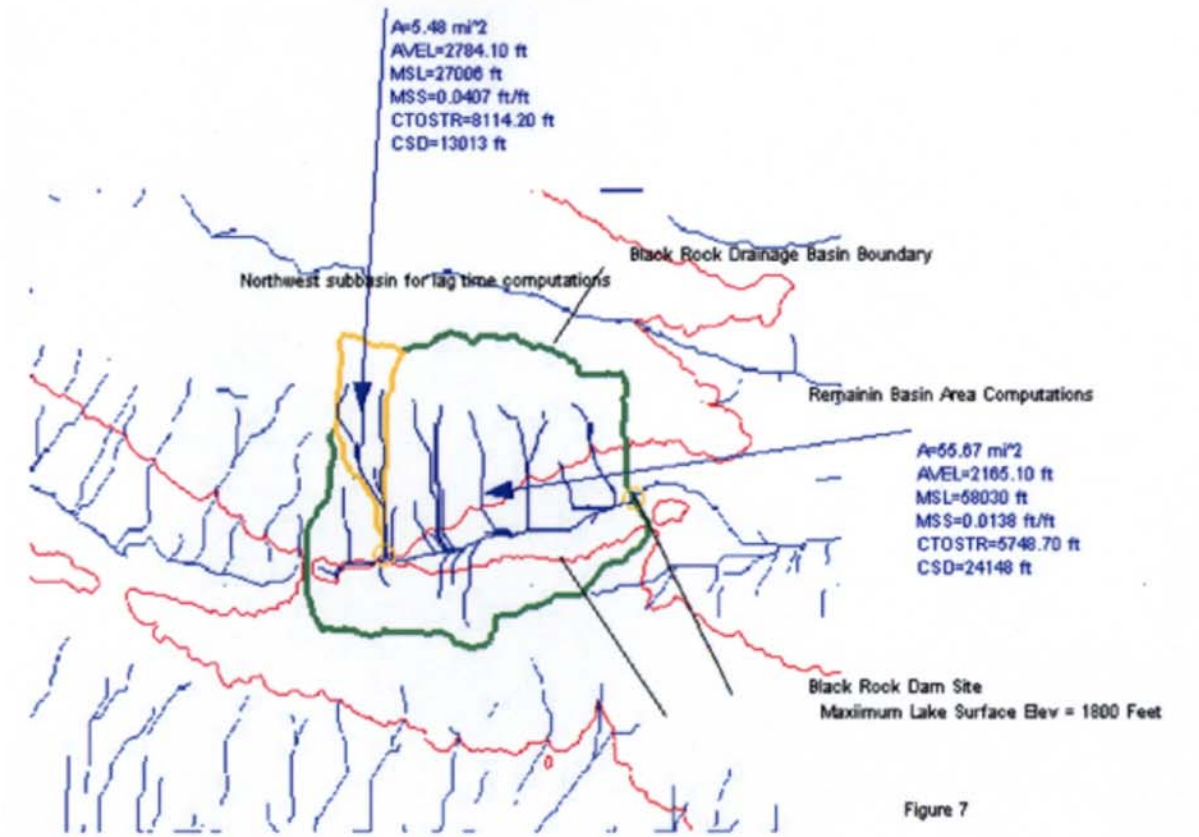
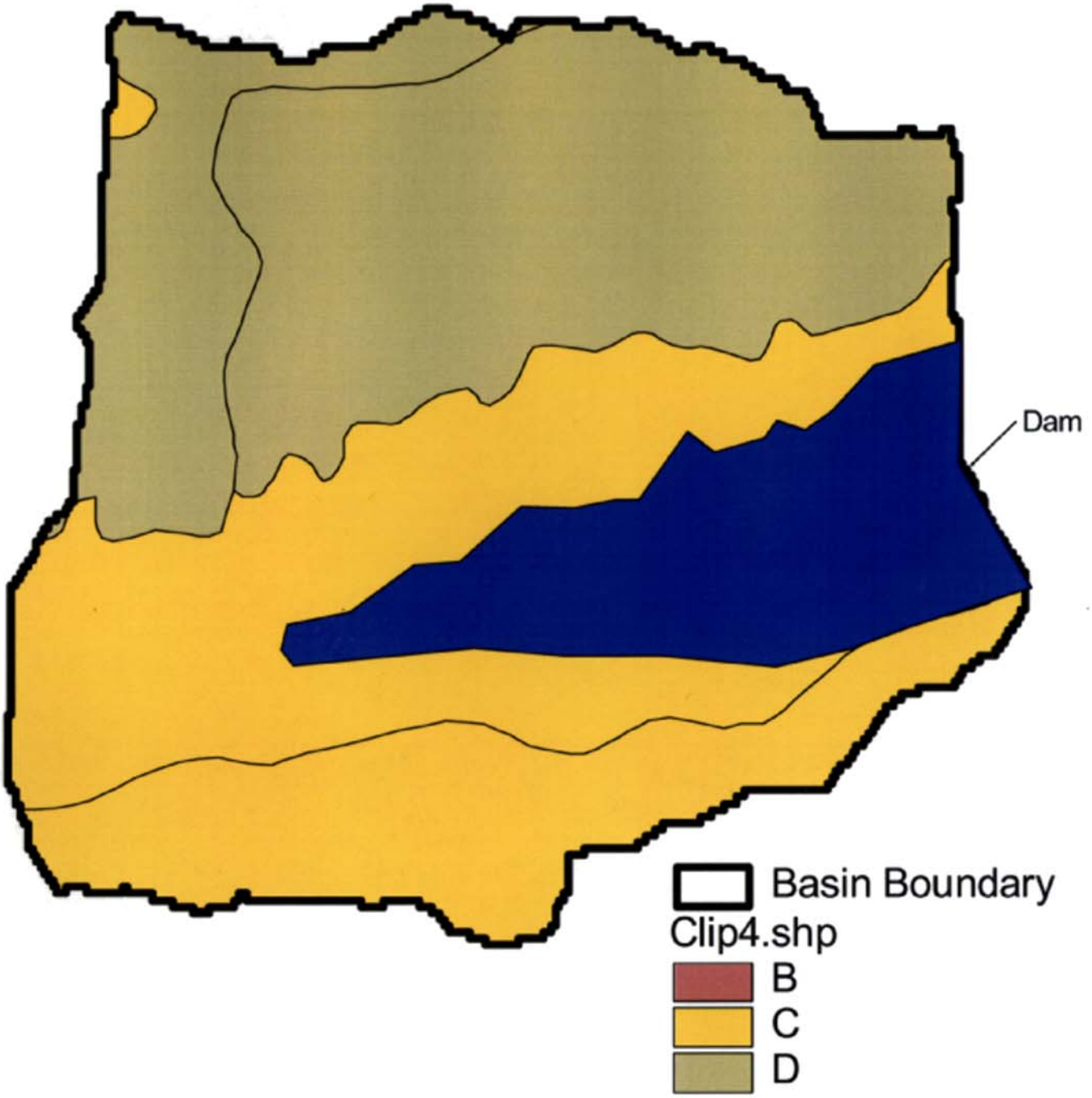
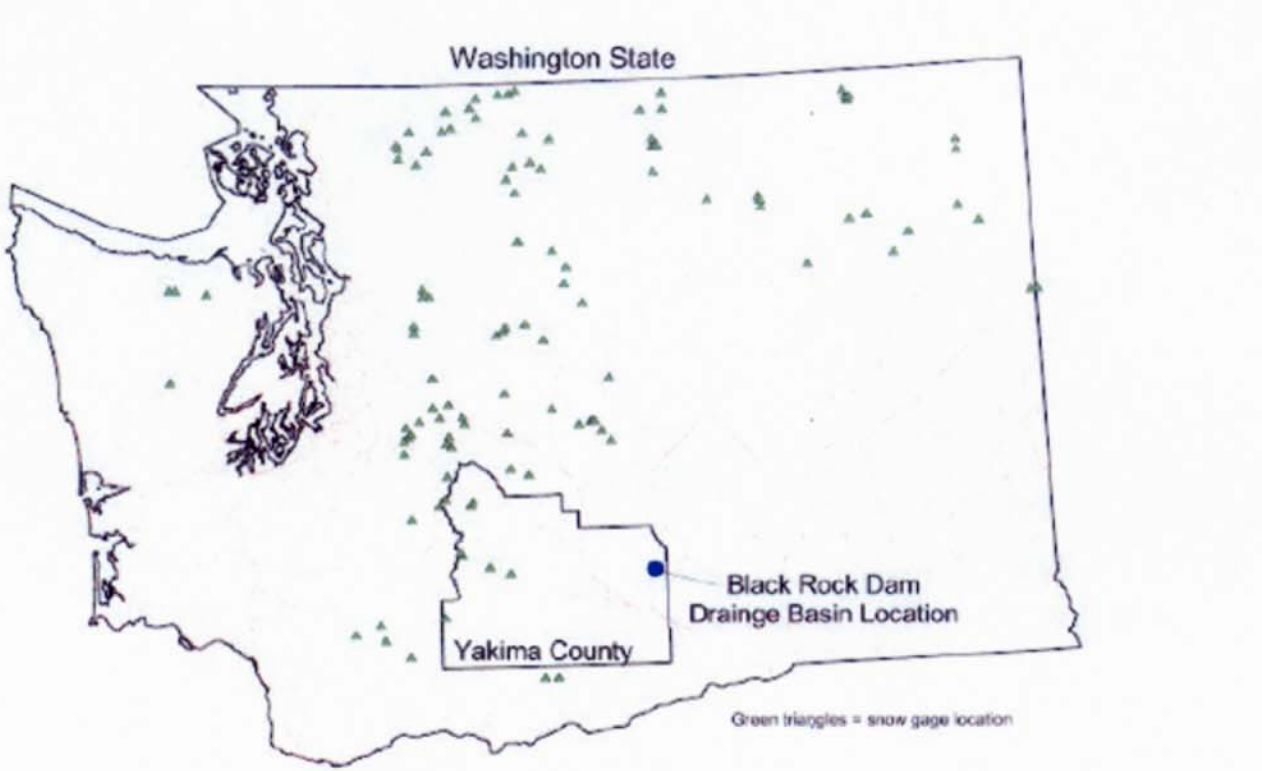

A=5.48 mi^2
AVEL=2784.10 ft
MSL=27006 ft
MSS=0.0407 ft/ft
CTOSTR=8114.20 ft
CSD=13013 ft
Black Rock Drainage Basin Boundary
Northwest subbasin for lag time computations
Remainin Basin Area Computations
A=55.67 mi^2
AVEL=2165.10 ft
MSL=58030 ft
MSS=0.0138 ft/ft
CTOSTR=5748.70 ft
CSD=24148 ft
Black Rock Dam Site
Maximum Lake Surface Elev = 1800 Feet

Figure 7



Black Rock Dam, Washington
Drainage Basin
Hydrologic Soils Groups
From STATSGO Soils Database

Figure 8



Location of NRCS snow gage sites
in the state of Washington

Figure 9